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THE PERFORMANCE OF IRREGULAR BUILDING STRUCTURES USING PUSHOVER ANALYSIS

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Abstract. High-rise buildings are at risk of collapse due to the earthquake. One method for analyzing earthquake loads is Pushover. Pushover is a non-linear static analysis to determine the behavior of a building collapse. This research was conducted to determine the performance of the setback building with a soft first story due to the earthquake based on the results of the pushover analysis curve. The structure is modeled as a 2-dimensional portal with a form of structural irregularity (setback with the soft first story) which consists of 2 structural models with different setback area ratios. The results of the analysis of this study indicate that the maximum shear force based on capacity curves in type 1 and type 2 buildings are 50260549.81 N and 53560488.63 N. Buildings with smaller setback area ratios, i.e., type 2 buildings have displacement, story drift, and base shear are more significant than type 1 buildings. Performance of type 1 and Type 2 building structures that refer to ATC-40 and FEMA 356 is at the Damage Control level.

Keywords : Pushover, Setback, Soft First Story

1. INTRODUCTION

High-rise buildings will collapse if not properly designed and built under existing rules and regulations [1] [2]. Building design nowadays often uses performance-based building planning or called performance-based design. In this study, the structure is modeled as a 2-dimensional portal in the form of irregular structure (setback with the soft first story) which consists of 2 structural models with different setback area ratios[3].

In this design, the performance of a building against an earthquake can be seen its collapse mechanism in the form of a curve. Pushover analysis or also called static thrust load analysis is needed to determine the pattern of collapse in the building [4]. In addition to obtaining the failure mechanism, with pushover analysis, it can be seen that the performance level of a building that refers to FEMA 356 and ATC 40 [5] [6]. A study on soft-story buildings obtained the maximum deviation occurred before the collapse, the level of structural performance based on FEMA-365 is at the Damage Control level that is the condition of the building has not suffered significant damage and can be re-functioned [3] [7].

2. METHODS

In this study, the authors designed an irregular building that is a setback building with a soft first story. The building functions as an office building, which consists of 10 floors. Ratio setback area to the lower story area of building type 1 is 0.3, and building type 2 is 0.6. Based on preliminary design results, the thickness of the floor plate is 12 cm, the dimensions of the beam are 65x40 cm, while the columns are distinguished on every three floors, on floors 1-4 120x120 cm, on floors 5-7 100x100 cm, and floors 8-10 90x90 cm [8] [9]. The building structure system uses a special moment bearing frame system.

3.1 Design Data

In this research, the building is planned to be in Semarang in a strong earthquake zone, with a soft soil type [10]. The building structure system uses a special moment bearing frame system, with 40 MPa steel quality (fy) and 35 MPa concrete quality (f'c).

Research in this study includes several stages, including preliminary design, calculation of loading, structural modeling, structural analysis, and pushover analysis. The flow chart in this final project research is presented in Figure 1.

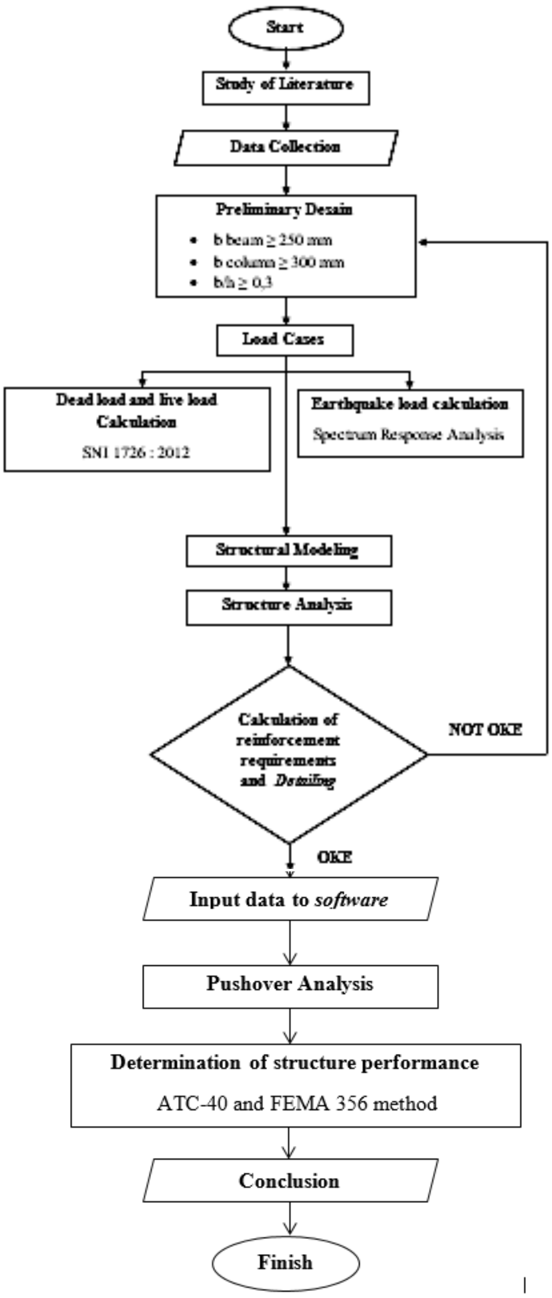

Figure 1. Flow Chart

3. RESULTS AND DISCUSSION

3.1 Modeling and Analysis of Building Type 1

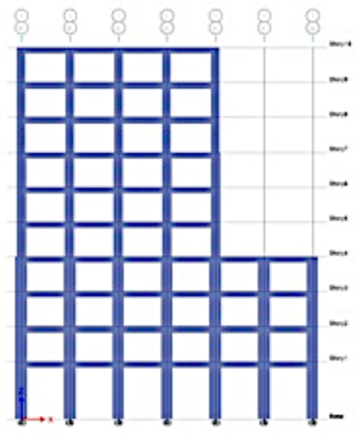

Figure 2. elevation view (Building Type 1)

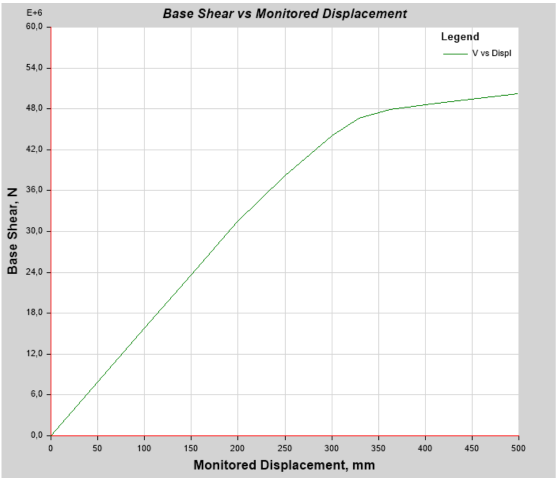

Figure 3. Pushover curve (Building type 1)

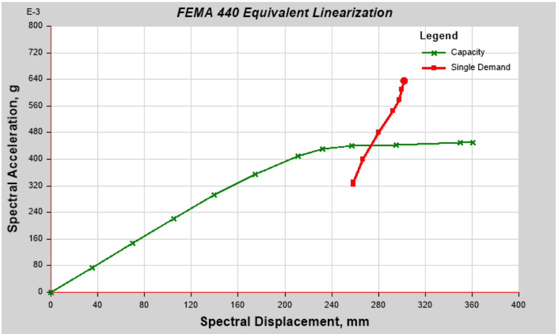

Figure 4. capacity spectrum curve ATC 40 (Building type 1)

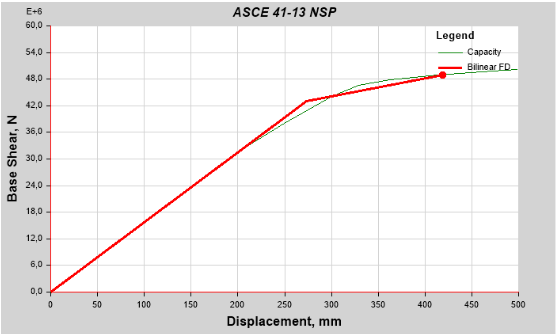

Figure 5. Bilinear curve FEMA 356 (Building type 1)

3.2 Modeling and Analysis of Building Type 2

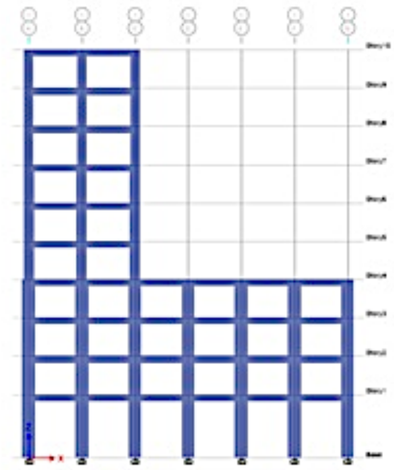

Figure 6. elevation view (Building Type 2)

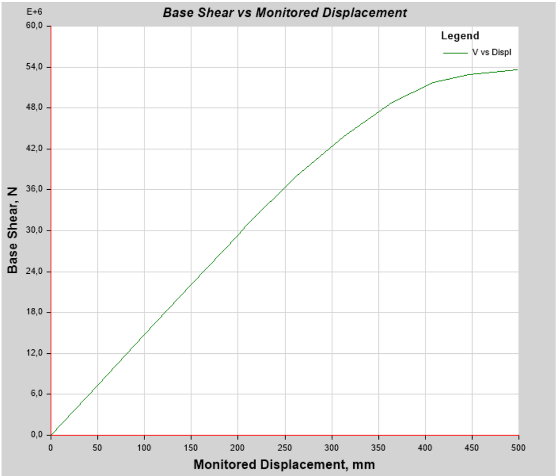

Figure 7. Pushover curve (Building type 1)

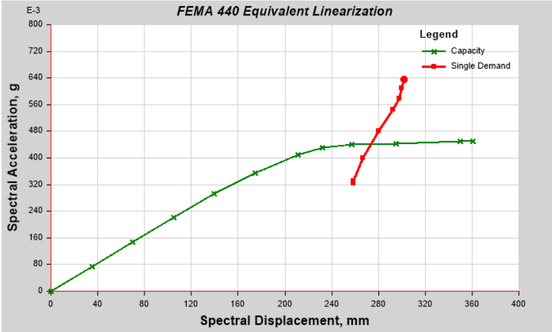

Figure 8. capacity spectrum curve ATC 40 (Building type 2)

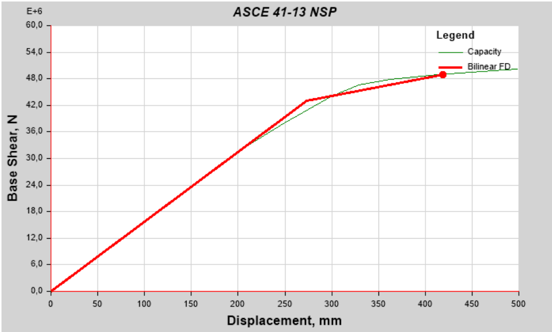

Figure 9. Bilinear curve FEMA 356 (Building type 2)

3.3 Pushover Analysis

3.3.1 Displacement

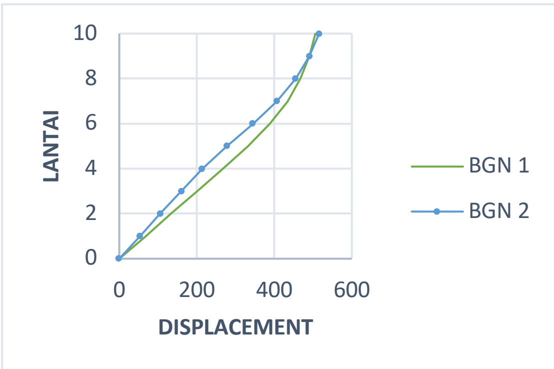

Figure 10. Displacement of Type 1 and Type 2 Building in the X-Direction

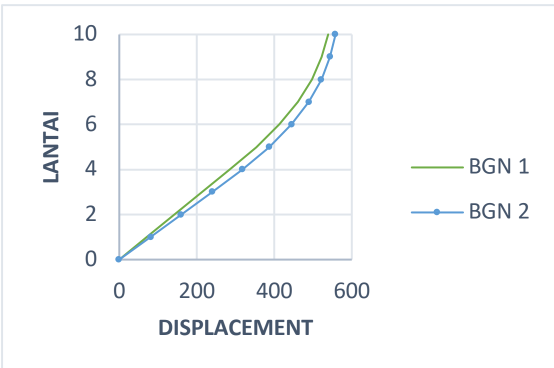

Figure 11. Displacement of Type 1 and Type 2 Building in the Y-Direction

Based on the results of pushover analysis, it is shown that the building that has the maximum displacement in the X direction (Figure 10) and the Y direction (Figure 11) is in type 2 buildings, ie buildings with a ratio of setback area smaller than type 1 buildings namely 515.68 mm in X direction and 558,105 mm in the Y direction. The results are following one of the journals in which the most significant displacement was in a regular building.[1][11].

3.3.2 Story Drift

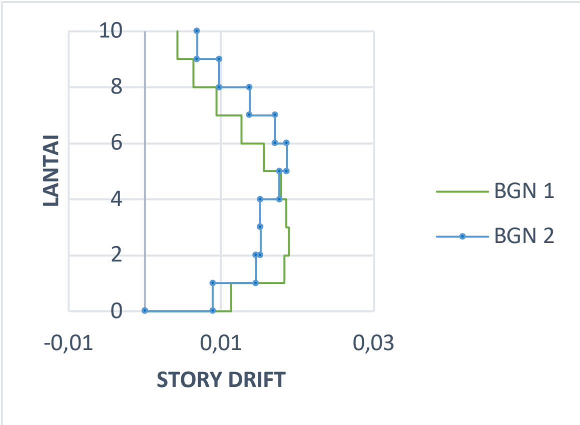

Figure 12. Story Drift of Type 1 and Type 2 Building in the X-Direction

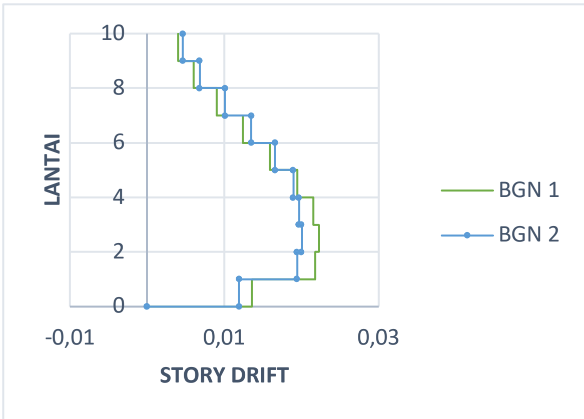

Figure 13. Story Drift of Type 1 and Type 2 Building in the Y-Direction

Based on the results of pushover analysis shows that the building that has the most significant story drift in the X direction (Figure 12) and the Y direction (Figure 13) is in the type 2 building that is the building with a setback area ratio smaller than the type 1 building that is, 0.0186 in the direction X and 0.0043 in the Y-direction. The results are per one of the journals wherein the study the most significant story drift was in a regular building [1] [12][13]

3.3.3 Base Shear

Table 1. Maximum Base Shear

Building Type	Maximum Displacement	Maximum Base Shear
	mm	KN
Type 1	499,308	50260,549
Type 2	499,654	53560,488

3.4 Performance Level Result

Table 2. Performance Level Result

	Direction	Parameter	Pushover Analysis Result	
			ATC-40	FEMA 356
Type 1	x-x	Performance Point, Δ_m (m)	0,432	0,525
		Actual Drift	0,011	0,013
		Performance level	*Damage Control*	*Damage Control*
	y-y	Performance Point, Δ_m (m)	0,445	0,595
		Actual Drift	0,012	0,015
		Performance level	*Damage Control*	*Damage Control*
Type 2	x-x	Performance Point, Δ_m (m)	0,403	0,720
		Actual Drift	0,010	0,018
		Performance level	*Damage Control*	*Damage Control*
	y-y	Performance Point, Δ_m (m)	0,403	0,705
		Actual Drift	0,010	0,018
		Performance level	*Damage Control*	*Damage Control*

Based on Table 2 the level of structural performance based on ATC 40 and FEMA 356 is at the level of Damage Control which means the building is still able to withstand earthquakes that occur with minimal risk of human casualties [14] [15][16]. The results refer to a journal in which the setback building is at the Damage Control level [3].

4. CONCLUSION

From the results of the analysis and discussion of the two types of setback buildings with a soft first story, the following conclusions can be drawn:

1. The building that has the highest displacement in the X direction and the Y direction is in the type 2 building that is the building with a setback area ratio that is smaller than the type 1 building that is 515.68 mm in the X direction and 558.105 mm in the Y direction.
2. The building that has the most significant story drift in the X direction and the Y direction is in the type 2 building that is the building with a setback area ratio that is smaller than the type 1 building that is, 0.0186 in the X and 0 directions. 0043 in the Y direction.
3. Maximum shear forces based on capacity curves in type 1 and type 2 buildings are 50260.55 kN and 53560.49 kN.
4. The Structural performance level based on FEMA 356 displacement coefficient method and ATC-40 capacity spectrum method on both building types are at Damage Control level which means the building is still able to withstand earthquakes that occur and not experience significant damage.
5. In buildings type 1 and type 2, the first yielding occurs in the first beam then the column, which means the building is under the strong column weak beam system.

5. ACKNOWLEDGEMENT

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